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Use of NASA Satellite Data Improves Ozone Level Predictions in Air Quality State Implementation Plan (SIP) Modeling

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HIGHLIGHT: Techniques for using satellite data (MODIS, GOES) to specify photolysis* rates were incorporated into models used by state governments to set emission limits for ozone. Baseline runs showed that adding satellite data improved the photolysis rates and changed ozone levels in the model by up to 70ppb. The changes are due to a better specification of clouds that have a major impact on photolysis rates which are a first order parameter in determining photochemical production rates in models. EPA incorporated the technique into its Community Multi-scale Air Quality (CMAQ) System and was made part of EPA's official release of the CMAQ version 4.7, released in December 2008.

RELEVANCE: When ozone levels exceed air quality standards, states must adopt emission reductions to lower air quality levels, based on models of the atmosphere. It may cost industry and the public billions to reduce ozone levels by 20-30 ppb. Thus, the differences in predicted ozone levels of up to 70 ppb (as identified by this project) are huge relative to reductions needed. EPA recognized that improving the photolysis rates were critical to confidence in models, which is important for industry to accept the regulations without challenge. The new satellite techniques are now available for States to use in development of State Implementation Plans (SIP), which convey to EPA the path they will take to meet air quality standards.

*Photolysis rates: The chemical reaction rates from the splitting or decomposition of a chemical compound by means of light energy or photons.

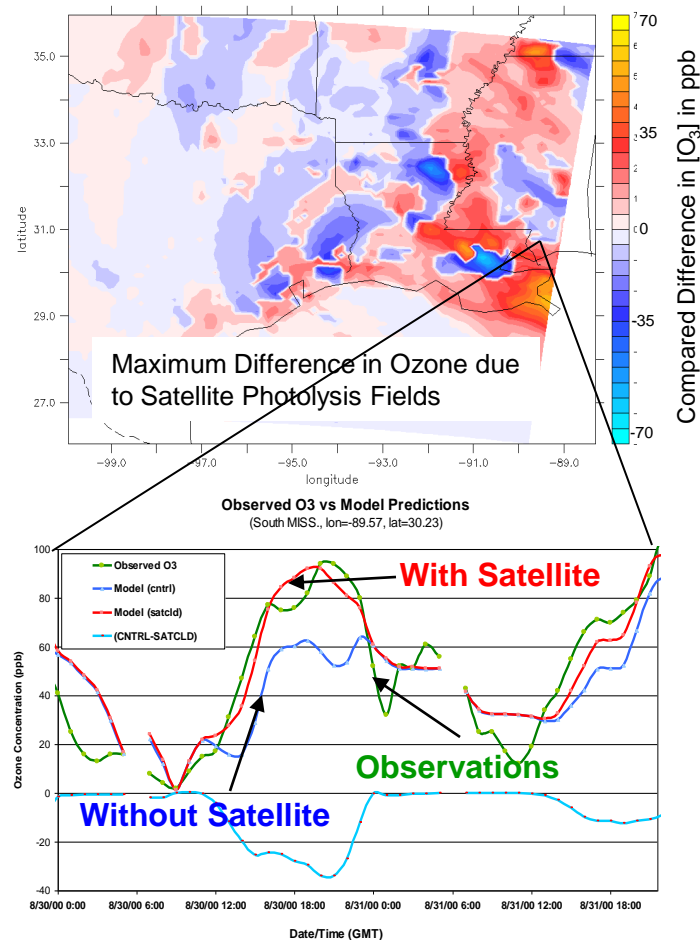


Figure 1: Top figure shows the differences in ozone between two CMAQ runs with and without use of satellite derived photolysis fields. Note the maximum differences exceed 50 ppb. Bottom figure shows time series of ozone prediction from the model vs. observations at an EPA monitoring site in South Mississippi.



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Primary Partners:
US EPA

Project Summary: The project improved the physical atmosphere in air quality models by assimilating satellite data. The models are used to test air quality emission control strategies by EPA, State and local air pollution regulatory agencies. The project used satellite data to improve the solar insolation, surface moisture, and surface heat capacity in the physical meteorological mode as well as the photolysis fields in the photochemical model. These parameters are used to create the atmosphere for AQ control strategy tests.

Earth Science Products: GOES visible and IR imager data are used to produce the time dependent cloud transmissivity and cloud tops used in the calculation of photolysis rates. MODIS emissivity products was tested in the model surface energy budget. The Gauiter/Diak model were used in the insolation retrievals. GOES IR imagery were used in the minimum albedo calculation and MODIS albedo products have been used for comparison. The McNider/Biazar model was used to provide satellite photolysis fields.

Technical Description of the Images:

Top Figure: The figure shows the differences in ozone between two CMAQ runs with and without use of satellite derived photolysis fields. By replacing model inferred to direct observed cloud transmissivity parameters, the photolysis fields specification was greatly improved. This type of chart helped convince EPA of the importance of this product.

Bottom Figure: This figure shows a time series of modeled ozone prediction with and without satellite data assimilation in southern Mississippi. The green line shows observations at this point, and without satellite assimilation (blue line), the model under-predicts ozone by nearly 40 ppb. When the direct observed cloud parameters were used, the levels are much closer to observations.

Application to Decision Making: Air quality control programs in the U.S are implemented by States and use models to ensure that emission reductions achieve National Ambient Air Quality Standards. The improved photolysis fields from satellite data established confidence in the models for industry acceptance.

Scientific Heritage: The data products and satellite assimilation techniques used here were developed and funded by the NASA Earth Science Program over the past 20 years. Some of the original work was funded in the mid-1980's under NASA research programs using satellite data to specify the role of cloud shading in the initiation and evolution of moist convection. The development of the satellite photolysis technique was introduced in McNider et al. 1998 and applied in its present form in by Pour-Biazar et al. 2007.

References: .

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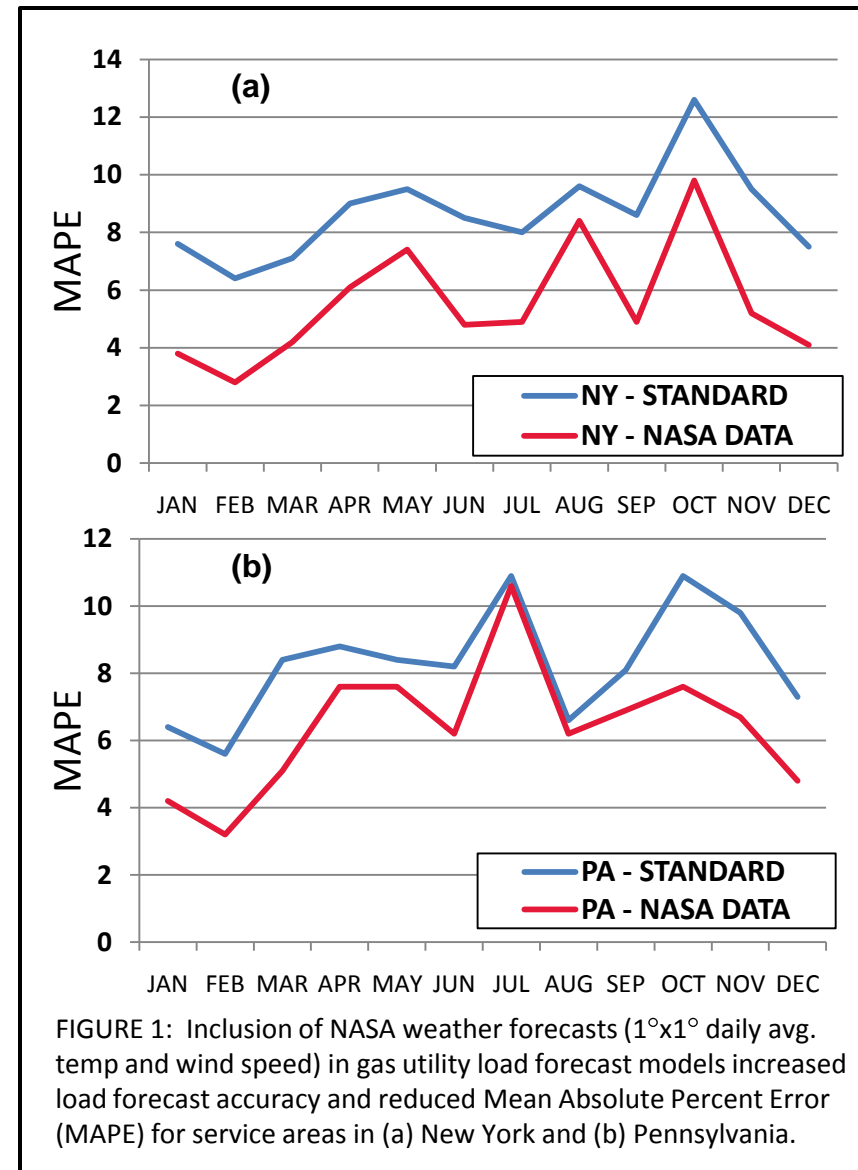


Using NASA Products to Enhance Energy Utility Load Forecasting

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HIGHLIGHT: The accuracy of next day natural gas load forecasts was improved on a monthly basis by up to 4.3 percentage points (mean absolute percent error, MAPE) when NASA weather parameters were used in load forecast models. MAPE is a measure used for determining forecast accuracy. Tests were conducted in which the gas loads for historical dates were forecasted twice: once, with ground-based weather parameters, and then with NASA weather parameters (e.g., temperature, precipitation) from the POWER project at LARC. After analyzing historical dates for service areas in New York and Pennsylvania, notable reductions in MAPE, indicating improved forecasts, were achieved throughout the year, especially during peak winter heating months. Residential and commercial heating drives the need for accurate gas forecasts during these high demand months.

RELEVANCE: Load forecasts are used by utility companies to plan for purchase of gas and electricity, as well as gas storage. Utilities rely on the load forecast models so they can anticipate demand for energy, in order to dispatch natural gas and to balance load on the electric grid. Uncertainties in load forecasts can be very costly to utility companies. For gas utilities, more accurate load forecasts will reduce the costs associated with: the purchase of high-priced, short-notice “spot gas”, large regulatory penalties incurred when they fail to meet demand, labor in manual relighting of thousands of customer pilot lights after a shortfall, and purchase and storage of extra “swing volume” to ensure ability to meet demand.





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Primary Partners:
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Project Summary: This project is demonstrating possible improvements in short-term utility load forecast by adding NASA weather parameters to existing load forecast tools and then through operational testing at selected utilities (gas and electric). We are working with utilities in 4 states (Gas- NY, WA and Electric- MD, AR). In the last year, we worked on historical testing using data from the POWER project. In the next two years, we will transition NASA resources for sustained use in a variety of utility load forecasting tools nationwide.

Earth Science Products: This project uses temperature, relative humidity, precipitation, wind speed and direction, cloud cover, and solar insolation from three sources: the POWER and Sustainable Buildings projects at NASA Langley (1°x1°, daily averages), the Weather Research & Forecast (WRF) model at NASA MSFC SPoRT Center (4 km x 4 km, hourly, to 36 hours), and the NWS National Digital Forecast Database (NDFD) gridded format (5 km x 5 km, 3- or 6-hourly, to 7 days).

Technical Description of the Images: Figure 1 shows mean absolute percent error (MAPE) of short-term gas load forecasts. Results of a load forecast model (Ventyx) were compared with actual historic load demand to determine MAPE of the forecasts. The blue lines show results using standard ground-based weather parameters. The red lines show results using gridded NASA temperature and wind speed parameters (1°x1°, daily average). The figures show up to a 4.3% reduction in MAPE in winter months, when accuracy of load forecast is most important for both supply and cost.

Application to Decision Making: Gas load forecast models often use weather forecasts from one or a few land-based weather stations within a utility's service area, and the addition of gridded NASA weather forecasts allowed the models to capture both microclimates and larger patterns across the service area and forecast load more accurately. Better load forecasts allow natural gas utilities to plan more precisely in the short term (1 to 10 days). One analysis estimated that a 10% improvement in 24-hour weather forecast accuracy (and resulting improved load forecasts) would save U.S. gas utilities millions of dollars per year through reduction of required swing volume alone (NOAA, 2002).

Scientific Heritage: This work applies improved weather forecasts obtained through assimilating satellite data into high-resolution weather models. Recent advances that have enabled & improved this work include a) use of MODIS sea surface temperature to improve prediction of temperature, dew point, winds, clouds, and precipitation patterns in coastal regions (Haines 2007) and b) land surface initialization with the NASA-developed Land Information System (LIS) to forecast surface temperature fields (Case 2008), and c) assimilation of profiles and radiances from AIRS to improve forecasts of temperature, clouds and precipitation patterns over the continental U.S. in 0-48h forecasts with a research version of WRF and the operational WRF (NAM) model run by NCEP (McCarty 2009).

References: NOAA, 2002. Geostationary Operational Environmental Satellite System (GOES) GOES-R Sounder and Imager Cost/Benefit Analysis (CBA).
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Haines, S. L., G. J. Jedlovec, and S. M. Lazarus, 2007: A MODIS Sea Surface Temperature Composite for Regional Applications. Trans. Geosci. Rem. Sens., 45, No. 9.
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World Bank NASA Satellite Training

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Objective: Train World Bank employees the basics of how to access and use NASA data products & Air Quality imagery.

Accomplishments:

- **Conducted a 1-Day training** on 25-September-2009 for World Bank employees supporting or managing projects in Asia, Africa, and Latin America. Trainees included a Climate Change Team member-Senior environmental Specialist, and representatives from the Urban and Social development team, totaling 12 people for a one day (8 hour) training session.
- **Completed several hands-on Case Studies:**
Attendees learned NASA data characteristics and interpretation, and their application by means of a Case Studies which included dust storms and/or smoke events in western and northern Africa and in the Middle East.
- **Products covered in presentations and hands-on activities:**
 - MODIS True Color Imagery and MODIS Aerosol Optical Depth
 - OMI NO₂ (nitrogen dioxide) and OMI Aerosol Index
 - CALIPSO vertical profiles
- The World Bank did an evaluation via a post-workshop survey. Attendees reported **relevance of NASA data products** for decision making support in their projects/countries of interest, such as urban air quality and water pollution due to atmospheric emissions. Attendees also reported that the training activity provided the tools to further explore additional NASA data sets and/or areas of application.

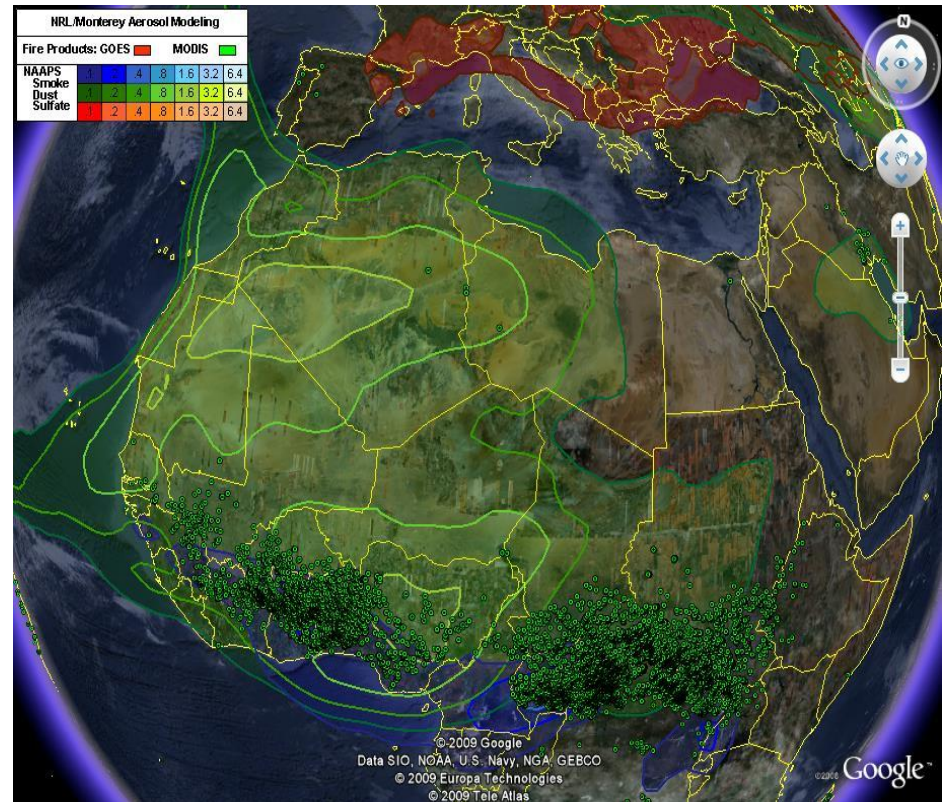


Image from one of the training Case Studies.

This image from a 26-December-2008 case study showing MODIS fire locations (green dots) and modeled pollution – dust (green), smoke (blue) and sulfates (red) - from the Naval Research Laboratory's Fire Locating and Modeling of Burning Emissions (FLAMBE) Program, which incorporates NASA satellite real-time observations in its model predictions.